# SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, TOSHIYUKI ENOMOTO, a citizen of Japan residing at Tokyo, Japan, YASUHIRO TANI, a citizen of Japan residing at Tokyo, Japan and KEI ETOH, a citizen of Japan residing at Tokyo, Japan have invented certain new and useful improvements in

WORKING FLUID, WORKING PROCESS USING THE WORKING FLUID, AND METHOD OF PRODUCTION OF THE WORKING FLUID

of which the following is a specification:-

## BACKGROUND OF THE INVENTION

1. Field of The Invention

The present invention relates to a working fluid which is supplied to a working point where a working of a workpiece is performed with the working fluid, a working process which performs the working of a workpiece by using the working fluid supplied to the working point, and a method of production which produces the working fluid.

2. Description of The Related Art

In conventional metalworking processes, working fluids fulfill basically four major functions: lubrication, cooling, cleaning or chemical effects, and chip removal. In the majority of working fluids it is essential that a working fluid be supplied to the working point.

In recent years, there is an increasing demand for environmental protection in the field of metalworking as well. It is desirable to reduce as much as possible the amount of the working fluid needed to perform the metalworking of the workpiece. The reduction of the working fluid amount to the desired level is attributable to reduction of the cost of manufacture including the processing of liquid waste. Developments of many working fluids are directed to achieving environmental protection by using the working fluid materials including harmless components that are not harmful to the environment as well as the workers. See Japanese journal "Machines And Tools", September 1997, pp.31-34, and

Japanese journal "Mechanical Technology", May 1999, pp.43-46.

As to the reduction of the working fluid amount to the desired level, some improvements of the working fluids or the working processes have been proposed. For example, some improved working fluid is aimed at achieving excellent cooling effects on the workpiece while supplying a small amount of the working fluid to the working point.

Additionally, as disclosed in Japanese Patent Application No.3-290958 and Japanese Laid-Open Patent Application No.5-329742, a foam-state machining fluid that can reduce the amount of the working fluid to such a desired level needed to perform the machining of a workpiece is known. Even if a small amount of the foam-state machining fluid is supplied to the working point where the machining of the workpiece is performed, the foam-state machining fluid can stay at the working point for a relatively long time during the machining. It is possible to achieve good cooling and lubrication effects on the workpiece even when a small amount of the foam-state working fluid is supplied to the working point.

However, in the case of the foam-state working fluid of the above-mentioned documents, it is difficult that the foam-state working fluid enters the working point of a workpiece the working of which is performed under extremely high pressure. Hence, when the working point is under extremely high pressure, the foam-state working fluid is inappropriate for the working of the workpiece.

Further, some working-fluid manufacturer has marketed an

emulsion-state working fluid which is aimed at reducing the working fluid amount to the desired level. It is made certain that the emulsion-state working fluid is more appropriate for the working of the workpiece while reducing the working fluid amount to the desired level, for at least the following reason.

Generally, oil-based fluids can provide better lubrication effects on the workpiece than water-based fluids. The oil-based working fluids are effective in providing good lubrication effects on the workpiece. However, the oil-based working fluids have a relatively high viscosity as compared with that of water-based working fluids. When the working point is subjected to extremely high pressure, it is difficult that the oil-based working fluids enter the working point of the workpiece under extremely high pressure because of the high viscosity thereof.

On the other hand, in the emulsion-state working fluid, the oil is dispersed in water with the aid of a surface-active substance, and the viscosity of the emulsion-state working fluid is apparently decreased from the level of viscosity of the non-emulsion-state working fluid. Because of the decreased viscosity, the emulsion-state working fluid can easily enter the working point of the workpiece. From this standpoint, the emulsion-state working fluid appears to be appropriate for performing the working of the workpiece under extremely high pressure.

Further, even if a small amount of the emulsion-state working fluid is supplied to the working point where the working of the

workpiece is performed, the emulsion-state working fluid can stay at the working point for a relatively long time during the working. The emulsion-state working fluid appears to be effective in providing good cooling and lubrication effects on the workpiece even when a small amount of the emulsion-state working fluid is supplied to the working point.

However, the emulsion state of a conventional emulsion-state working fluid is quickly collapsed due to the working pressure at the working point or others after it is supplied to the working point. Further, in the case of the metalworking of a metal workpiece, the surface-active substance of the emulsion-state working fluid reacts with the metal ions of the workpiece surface, and the emulsion state of the working fluid is quickly collapsed or deteriorated by the reaction. Because of the reaction of the surface-active substance and the metal ions or the working pressure, the time the emulsion state of the working fluid is held is shortened, which will be detrimental to achieving good lubrication and cooling of the workpiece.

Additionally, when the working fluid from the working point is circulated in the working machine in order to reuse the working fluid for the working of the workpiece, the emulsion state of the working fluid is likely to be deteriorated during the circulation. Further, when the oil-based working fluid is dispersed in water-based (aqueous) solvent with the aid of the surface-active agent, nitrogen-based or chlorine-based surface-active agents are often

used. However, in order to meet the demand for environmental protection, it is desirable to reduce as much as possible the amount of nitrogen or chlorine contained in the surface-active agents, used to provide the emulsion-state working fluid.

## SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved working fluid which can appropriately eliminate the collapsing of the emulsion state due to the working pressure or the deterioration of the emulsion state due to the circulation of the working fluid, and is effective in providing good cooling and lubrication effects on the workpiece even when a small amount of the working fluid is supplied to the working point.

Another object of the present invention is to provide a working process which performs the working of a workpiece by using a working fluid, the working fluid appropriately eliminating the collapsing of the emulsion state due to the working pressure or the deterioration of the emulsion state due to the circulation of the working fluid, and being effective in providing good cooling and lubrication effects on the workpiece even when a small amount of the working fluid is supplied to the working point.

Another object of the present invention is to provide a method of production of a working fluid which can appropriately eliminate the collapsing of the emulsion state due to the working pressure or the deterioration of the emulsion state due to the circulation of the working fluid,

working fluid, and is effective in providing good cooling and lubrication effects on the workpiece even when a small amount of the working fluid is supplied to the working point.

According to one preferred embodiment of the invention, a working fluid, which is supplied to a working point where a working of a workpiece is performed with the working fluid, contains a solvent, and microcapsules filled with liquid-state substances, the microcapsules being dispersed in the solvent.

According to another preferred embodiment of the invention, a working process performs a working of a workpiece with a working fluid, the working fluid containing a solvent and microcapsules filled with liquid-state substances, the microcapsules being dispersed in the solvent, the working process including the steps of: supplying the working fluid to a working point of the workpiece; and performing a cutting process of the workpiece at the working point while supplying the working fluid to the working point.

According to another preferred embodiment of the invention, a working process performs a working of a workpiece with a working fluid, the working fluid containing a solvent and microcapsules filled with liquid-state substances, the microcapsules being dispersed in the solvent, the working process including the steps of: supplying the working fluid to a working point of the workpiece; and performing a grinding process of the workpiece at the working point while supplying the working fluid to the working point.

According to another preferred embodiment of the present

invention, a working process performs a working of a workpiece with a working fluid, the working fluid containing a solvent and microcapsules filled with liquid-state substances, the microcapsules being dispersed in the solvent, the working process including the steps of: forming a mixture of the working fluid and abrasive particles; supplying the mixture of the working fluid and the abrasive particles to a working point of the workpiece; and performing a polishing process of the workpiece at the working point while supplying the mixture to the working point.

According to another preferred embodiment of the invention, a working process performs a working of a workpiece with a working fluid, the working fluid containing a solvent and microcapsules filled with liquid-state substances, the microcapsules being dispersed in the solvent, the working process including the steps of: supplying the working fluid to a working point of the workpiece; and performing a plastic deformation process of the workpiece at the working point while supplying the working fluid to the working point.

According to another preferred embodiment of the invention, a method of production of a working fluid which is supplied to a working point where a working of a workpiece is performed with the working fluid, the method of production including the steps of: producing microcapsules that are filled with liquid-state substances; and mixing the microcapsules and a solvent so that the microcapsules are dispersed in the solvent to form the working fluid,

wherein, in the producing step, a process, which is selected from the group including at least a surface polymerization process, an "in situ" polymerization process, a coacervation process, an immersion hardening/coating process and an immersion drying process, is performed to produce the microcapsules filled with the liquid-state substances.

In the above preferred embodiments of the invention, the working fluid contains the solvent and the microcapsules filled with the liquid-state substances, the microcapsules being dispersed in the solvent. Hence, the working fluid and the working process of the present invention are effective in providing good cooling and lubrication effects on the workpiece even when a small amount of the working fluid is supplied to the working point. The abrupt collapsing of the emulsion state due to the working pressure or the deterioration of the emulsion state due to the circulation of the working fluid, as in the conventional emulsion-state working fluid, can be appropriately eliminated.

Further, the method of production of the above preferred embodiment can provide the working fluid that is effective in providing good cooling and lubrication effects on the workpiece even when a small amount of the working fluid is supplied to the working point.

## BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the present invention

will be apparent from the following detailed description when read in conjunction with the accompanying drawings in which:

FIG. 1 is a diagram for explaining a cutting process in which the working process of the invention is embodied.

FIG. 2 is a diagram of a working fluid application device which is used to supply the working fluid of the invention to the working point.

FIG. 3 is a diagram for explaining a plastic working process in which the working process of the invention is embodied.

FIG. 4 is a diagram for explaining a grinding process in which the working process of the invention is embodied.

FIG. 5 is a diagram for explaining a polishing process in which the working process of the invention is embodied.



## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

A description will now be provided of preferred embodiments of the present invention with reference to the accompanying drawings.

The working fluid according to the present invention is supplied to a working point where a working of a workpiece is performed with the working fluid. The working fluid according to the present invention contains a solvent and microcapsules filled with liquid-state substances, the microcapsules being dispersed in the solvent. The liquid-state substances in the microcapsules of the working fluid provide lubrication, cooling and cleaning effects on

the workpiece when performing the working of the workpiece.

The working process according to the present invention is provided to perform a working of a workpiece with the working fluid being supplied to the working point. Further, the method of production according to the present invention is provided to produce the working fluid from source materials.

Next, a description will be provided of one preferred embodiment of the method of production of the working fluid according to the present invention.

The method of production of the present embodiment generally includes a producing step and a mixing step. In the producing step, microcapsules that are filled with liquid-state substances are produced. The microcapsules have a predetermined average particle size. In the mixing step, the microcapsules and a solvent are mixed in a given ratio so that the microcapsules are dispersed in the solvent to form the working fluid. The liquid-state substances in the microcapsules of the working fluid may include not only normal machining fluids (for example, lubricants) but also cleaning or chemical-effect liquids (for example, etchants).

In the producing step of the above production method, any suitable process, which is selected from the group including at least a surface polymerization process, an "in situ" polymerization process, a coacervation process, an immersion hardening/coating process and an immersion drying process, is performed to produce the microcapsules that are filled with the liquid-state substances

(lubricants or etchants).

When the surface polymerization process or the "in situ" polymerization process is performed as the selected process, the mixing step is performed by adjusting the mixing speed so as to create the emulsion state in which the microcapsules are dispersed in the solvent, and to allow the microcapsules to have an average particle size ranging from 0.1 $\mu m$ to 1000 $\mu m$.

As to the materials of the microcapsule walls, when the "in situ" polymerization process is performed as the selected process, an appropriate catalyst for the polymerization is supplied from the outer layer of the microcapsule core substances so that the microcapsule walls of a melamine resin or the like are formed thereon.

After the producing step is performed in this way, the microcapsules and the solvent are mixed in the given ratio in the mixing step, so that the microcapsules are dispersed in the solvent to form the working fluid. For example, the microcapsules are dispersed in water by the mixing. The solvent that is mixed with the microcapsules is preferably a water-based (aqueous) liquid. Alternatively, an oil-based liquid may be used instead. Further, when the necessity occurs, suitable surface-active agents or abrasive particles may be added to the solvent that is mixed with the microcapsules.

Next, a description will be provided of preferred embodiments of the working process according to the present invention. As

described above, the working process according to the present invention provided to perform the working of a workpiece with the working fluid being supplied to the working point. The working of the workpiece may include at least a cutting process, a plastic working process, a grinding process, and a polishing process.

FIG. 1 shows a cutting process in which the working process of the invention is embodied. In the present embodiment, a cutting tool, such as a milling cutter, is brought into contact with the workpiece at the working point, and, during the cutting process, the working fluid is continuously supplied to the working point at a controlled flow rate by using a working fluid application device having a nozzle.

As shown in FIG. 1, before a start of the cutting process, a cutting tool (for example, a milling cutter) 13 is brought into contact with a workpiece 14 at the working point. At a start of the cutting process, the working fluid application device (not shown) is controlled by a control unit (not shown), and a working fluid 12 in which the microcapsules filled with a machining fluid are dispersed in the solvent, is sprayed from a nozzle 11 of the working fluid application device onto the working point at a controlled flow rate.

FIG. 2 shows a working fluid application device which is used to supply the working fluid 12 to the working point in one preferred embodiment of the working process of the invention.

In the working fluid application device of FIG. 2, the working fluid 12 that is stored in a reservoir 19 is delivered to a pressure

tank 17 by controlling operation of a pump 18. A fluid surface sensor 16 is provided on the pressure tank 17, and this fluid surface sensor 16 outputs a signal, indicating the amount of the working fluid 12 contained in the pressure tank 17, to the control unit (not shown). The control unit detects the amount of the working fluid 12 within the pressure tank 17 based on the signal output by the fluid surface sensor 16. The control unit controls the operation of the pump 18 in accordance with the detected working fluid amount of the pressure tank 17, so that the top surface of the working fluid 12 within the pressure tank 17 is kept at a constant height.

Further, in the working fluid application device of FIG. 2, an air supplying device 20 is provided to supply compressed air to the pressure tank 17, the compressed air being at a given pressure. The working fluid 12 from the pressure tank 17 is delivered to the nozzle 11 via a flow control valve 15 with the aid of the compressed air. The control unit controls operation of the flow control valve 15, so that the flow of the working fluid delivered from the pressure tank 17 to the nozzle 11 is appropriately controlled by the control valve 15. Specifically, the control unit sets the opening position of the flow control valve 15 to one of a completely closed position, a completely open position, and a reduced-opening position, so that the working fluid 12 is sprayed from the nozzle 11 onto the working point at a controlled flow rate. The control unit controls the operation of the flow control valve 15 so that the spraying of the working fluid onto the working point is matched with the timing of

the placement of the cutting tool 13 onto the workpiece 14.

In the above-described embodiment, the working fluid from the working point is circulated in a working machine including a milling machine of the milling cutter 13, in order to reuse the working fluid for the working of the workpiece, which is not illustrated in FIG. 1.

In the above-described embodiment, the working fluid 12 from the pressure tank 17 is delivered through a single pipe to the nozzle 11. However, the present invention is not limited to this embodiment. Alternatively, a mixture of the working fluid 12 and the compressed air may be delivered through a double pipe to the nozzle 11, so that the fluid-air mixture is sprayed from the nozzle 11 onto the working point.

Further, in the above-described embodiment, the working fluid 12 is sprayed from the nozzle 11 of the working fluid application device onto the working point. However, the present invention is not limited to this embodiment. Alternatively, a cutting tool with an oil hole may be used instead, and the working fluid 12 may be sprayed from the oil hole of the cutting tool to the working point.

According to the working process of the present embodiment, the working fluid 12 contains the solvent and the microcapsules filled with the liquid-state substances (the machining fluid), the microcapsules being dispersed in the solvent. Regardless of the viscosity of the liquid-state substances, the microcapsules of the working fluid 12 have a low viscosity. The working fluid 12 can

easily enter the working point and the emulsion state of the microcapsules of the working fluid 12 is slowly collapsed by the working pressure at the working point. Hence, the working process of the present embodiment is effective in providing good cooling and lubrication effects on the workpiece even when a small amount of the working fluid 12 is supplied to the working point. The abrupt collapsing of the emulsion state due to the working pressure or the deterioration of the emulsion state due to the circulation of the working fluid, as in the conventional emulsion-state working fluid, can be appropriately eliminated.

FIG. 3 shows a plastic working process in which the working process of the invention is embodied. In the present embodiment, the plastic working process, such as bending or drawing, employs the working fluid 12, including the microcapsules, that is already applied to the workpiece surface (a single side or both sides of the workpiece), rather than continuously supplying the working fluid 12 to the working point at a controlled flow rate.

As shown in FIG. 3, before a start of the plastic working, a given amount of the working fluid 12 is applied to a sheet-like workpiece 14, and this workpiece 14 is held on a die 22. A holder plate 23 is placed thereon to fix the workpiece 14 on the die 22. At a start of the plastic working process, a punch 21 of a press (not shown) is lowered so that the workpiece 14 is allowed to draw into the die 22.

According to the working process of the present embodiment,

the surface of the workpiece 14 in contact with the punch 21 is subjected to the friction force and the deformation force, and the surface of the workpiece 14 in contact with the die 22 is subjected to the friction force. The working fluid 12 contains the solvent and the microcapsules filled with the liquid-state substances (the machining fluid), the microcapsules being dispersed in the solvent. Regardless of the viscosity of the liquid-state substances, the microcapsules of the working fluid 12 have a low viscosity. The given amount of the working fluid 12 is provided, in advance, to the working point, and the emulsion state of the microcapsules of the working fluid 12 is slowly collapsed by the working pressure at the working point. Hence, the working process of the present embodiment is effective in providing good cooling and lubrication effects on the workpiece 14. The abrupt collapsing of the emulsion state due to the working pressure at the working point, as in the conventional emulsion-state working fluid, can be appropriately eliminated.

FIG. 4 shows a grinding process in which the working process of the invention is embodied. In the present embodiment, a grinding wheel is brought into contact with the workpiece at the working point, and, during the grinding process, the working fluid 12, including the microcapsules (which are filled with a grinding fluid), is continuously supplied to the working point at a controlled flow rate from the nozzle 11 of the working fluid application device of FIG. 2. An upper or lower surface or an internal or external surface of the workpiece 14 is ground by the grinding wheel.

As shown in FIG. 4, a rotating table 44 is rotated around its central axis by a drive motor (not shown), and a disc-like workpiece14 is positioned and fixed on the rotating table 44. A grinding wheel 41 is attached to an end of a spindle 42, and the grinding wheel 41 is rotated around the spindle 42. The spindle 42 is supported by a supporting column 43. At a start of the grinding process, the workpiece 14, which is rotated on the rotating table 44 in a direction indicated by the arrow, may be moved to come in contact with the grinding wheel 41, which is rotated around the spindle 42 in a direction indicated by the arrow. Otherwise, the rotating grinding wheel 41 may be moved to bring the grinding wheel 42 into contact with the rotating workpiece 14. During the grinding process, the rotating grinding wheel 41 may be delivered at a constant speed in a longitudinal direction (indicated by the arrow "Y" in FIG. 4). The rotating table 44 is provided on a movable table 45, and the movable table 45 is provided so that it is movable in both a lateral direction (indicated by the arrow "X" in FIG. 4) and a vertical direction (indicated by the arrow "Z" in FIG. 4). Further, during the grinding process, the working fluid 12 in which the microcapsules filled with the grinding fluid are dispersed in the solvent is sprayed at a controlled flow rate from the nozzle 11 of the working fluid application device of FIG. 2 onto the working point between the workpiece 14 and the grinding wheel 41.

In the grinding process of FIG. 4, the grinding depth (in the direction "Z") is adjusted, and one of the workpiece 14 and the

grinding wheel 41 is moved in the direction X or the direction Y to the other. While the working fluid 12 is continuously supplied to the working point, the workpiece 14 is rotated on the rotating table 44 in the indicated direction and the grinding wheel 41 is rotated around the spindle 42 in the indicated direction.

According to the grinding process of the present embodiment, any of a side-cut grinding, a precision grinding or a spark-out grinding may be carried out. Similar to the cutting process of FIG. 1, the working fluid 12 contains the solvent and the microcapsules filled with the liquid-state substances (the grinding fluid), the microcapsules being dispersed in the solvent. Regardless of the viscosity of the liquid-state substances, the microcapsules of the working fluid 12 have a low viscosity. Even when a small amount of the working fluid 12 is supplied to the working point, the emulsion state of the microcapsules of the working fluid 12 is slowly collapsed by the working pressure at the working point. Hence, the working process of the present embodiment is effective in providing good cooling and lubrication effects on the workpiece 14. The abrupt collapsing of the emulsion state due to the working pressure at the working point or the deterioration of the emulsion state due to the circulation of the working fluid, as in the conventional emulsion-state working fluid, can be appropriately eliminated.

FIG. 5 shows a polishing process in which the working process of the invention is embodied. In the present embodiment, an abrasive tape is brought into contact with the workpiece at the

working point, and, during the polishing process, the working fluid 12, including the microcapsules (which are filled with a polishing fluid), is continuously supplied to the working point at a controlled flow rate from the nozzle 11 of the working fluid application device of FIG. 2. An upper or lower surface (or an internal or external surface) of the workpiece 14 is polished by the abrasive tape.

As shown in FIG. 5, an abrasive tape 32 in which the abrasive is bonded with an appropriate bonding agent into the tape 32, is brought into contact with the workpiece while the working fluid 12 is continuously supplied to the working point between the workpiece and the abrasive tape 32. A rotating table 31 is rotated around its central axis by a drive motor (not shown), and a disc-like workpiece14 is positioned and fixed on the rotating table 31. The abrasive tape 32 is rotated by a drive mechanism (not shown) in a direction indicated by the arrow in FIG. 5. A pressure roller 33, which is provided to be movable in a radial direction of the disc-like workpiece 14, is depressed on the abrasive tape 32 so that the abrasive tape 32 contacts the workpiece 14 under a given pressure. During the polishing process, the working fluid 12 in which the microcapsules filled with the polishing fluid are dispersed in the solvent is sprayed at a controlled flow rate from the nozzle 11 of the working fluid application device of FIG. 2 onto the working point between the workpiece 14 and the abrasive tape 32. While the working fluid 12 is continuously supplied to the working point, the workpiece 14 is rotated on the rotating table 31 in the indicated

direction and the abrasive tape 32 is rotated in the indicated direction. At the same time, the pressure roller 33 is moved at a constant rate in the radial direction of the disc-like workpiece 14 so that the polishing of the workpiece 14 is carried out.

In the above-described embodiment, only one nozzle 11 of the working fluid application device is provided. The number of the nozzles 11 that are provided in the polishing equipment may be altered depending on the width dimension of the abrasive tape 32.

In the above-described embodiment, the abrasive tape 32 is provided to polish the disc-like workpiece 14. Alternatively, another polishing tool (for example, an abrasive cloth) may be used according to the type of the workpiece.

According to the polishing process of the present embodiment, the working fluid 12 contains the solvent and the microcapsules filled with the liquid-state substances (the polishing fluid), the microcapsules being dispersed in the solvent. Regardless of the viscosity of the liquid-state substances, the microcapsules of the working fluid 12 have a low viscosity. Even when a small amount of the working fluid 12 is supplied to the working point, the emulsion state of the microcapsules of the working fluid 12 is slowly collapsed by the working pressure at the working point. Hence, the working process of the present embodiment is effective in providing good cooling and lubrication effects on the workpiece 14. The abrupt collapsing of the emulsion state due to the working pressure at the working point or the deterioration of the emulsion state due to

the circulation of the working fluid, as in the conventional emulsion-state working fluid, can be appropriately eliminated.

Next, a description will be provided of one preferred embodiment of the working fluid of the invention.

In the present embodiment, by performing either the surface polymerization process or the "in situ" polymerization process, microcapsules that are filled with an oil-based cutting fluid are produced. In the mixing step, the microcapsules and water are mixed in a given ratio so that the microcapsules are dispersed in water to form the working fluid. In the present embodiment, the working fluid containing the microcapsules filled with the cutting fluid, the microcapsules being dispersed in water, is produced for use in the cutting process. The mixing speed is suitably adjusted so as to create the emulsion state in which the microcapsules are dispersed in water, and to allow the microcapsules to have an average particle size ranging from 0.1 $\mu m$ to 1000 $\mu m$.

As to the materials of the microcapsule walls, when the "in situ" polymerization process is performed, an appropriate catalyst for the polymerization is supplied from the outer layer of the microcapsule core substances so that the microcapsule walls of a melamine resin are formed thereon.

For the purpose of comparison, three types of fluid: water, the cutting fluid (filled into the microcapsules), and the working fluid of the above embodiment (containing the microcapsules) are respectively supplied to the working point where a cutting process of

a stainless steel workpiece is performed. As a result, in the case of water, even if a large amount of water is supplied, the lubrication effects on the workpiece has been extremely low, and the cutting of the workpiece cannot be achieved. In the cases of the cutting fluid and the working fluid of the above embodiment, the cutting of the workpiece has been normally performed.

Further, by reducing the flow rate of the working fluid supplied to the working point, the cutting of the workpiece is performed for the cases of the cutting fluid and the working fluid of the above embodiment. As a result, in the case of the working fluid of the above embodiment, even when the flow rate is reduced to 0.5 ml/hour, the cutting of the workpiece has been normally performed. However, in the case of the cutting fluid, when the flow rate is reduced to 3 ml/hour, the cutting of the workpiece cannot be performed.

Therefore, it is made certain that, according to the working fluid of the above embodiment, it is possible to achieve good cooling and lubrication effects on the workpiece even when a small amount of the working fluid is supplied to the working point.

The present invention is not limited to the above-described embodiments, and variations and modifications may be made without departing from the scope of the present invention.

Further, the present invention is based on Japanese priority application No.11-359342, filed on December 17, 1999, the entire contents of which are hereby incorporated by reference.